View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by VU Research Portal

UNIVERSITEIT AMSTERDAM

VU Research Portal

A meta-framework for sustainability assessment

Sala, S.; Ciuffo, B.; Nijkamp, P.

2013

document version
Early version, also known as pre-print

Link to publication in VU Research Portal

citation for published version (APA)
Sala, S., Ciuffo, B., & Nijkamp, P. (2013). *A meta-framework for sustainability assessment*. (Research Memorandum; No. 2013-16). Faculty of Economics and Business Administration.

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:
vuresearchportal.ub@vu.nl

Download date: 21. May. 2021

Faculty of Economics and Business Administration

A meta-framework for sustainability assessment

Research Memorandum 2013-16

Serenella Sala
Biagio Ciuffo
Peter Nijkamp

vrije Universiteit amsterdam

A Meta-Framework for Sustainability Assessment

Serenella Sala
European Commission - Joint Research Centre
Institute for Environment and Sustainability,
Via Enrico Fermi 2749
21027 Ispra (VA), Italy
Email: serenella.sala@jrc.ec.europa.eu

Biagio Ciuffo
European Commission - Joint Research Centre
Institute for Environment and Sustainability,
Via Enrico Fermi 2749
21027 Ispra (VA), Italy
Email: biagio.ciuffo@jrc.ec.europa.eu

Peter Nijkamp
VU University Amsterdam
Department of Spatial Economics
De Boelelaan 1105
1081HV Amsterdam, The Netherlands
Email: p.nijkamp@vu.nl

Abstract
Assessing sustainability is increasingly becoming a common practice in the appraisal of products and policy plans. Nonetheless, there are many concerns about the operationalisation of sustainability assessment. In the present paper we discuss the distinction between integrated assessment and sustainability assessment (SA), and using a systemic approach, we propose how to move from integrated assessment to SA. The fundamental differences may be identified at three levels: ontological, methodological and epistemological. These differences arise from the need to capture complexity while ensuring transparency, comprehensiveness, completeness and legitimacy. A review of the state of the art suggests that there is a lack of both science-based and policy-based boundaries which are able to define a threshold between sustainability and non-sustainability. To address these concerns, we present a systematic methodological framework for SA, based on a literature meta-review of multi-scale and multi-purpose appraisal methodologies and related methods, models, and indicators. To overcome ambiguity, a clear transparency and clarity in value setting is needed. In this framework, SA is considered as a structured procedure encompassing different field-specific analytical methods and models, depending on the specific application (e.g. assessment of policy, plans, or products) and decision context (e.g. time, scale, actors). External inputs to the methodology are the "values" to be considered in the analysis and the (political) boundaries defined for them, including also the sustainability framework in which the analysis is carried out (e.g. "weak" vs. "strong"). Internal elements of the methodology comprise the choice of the approach (e.g. "what-if" vs. "what-to"), the scenario settings and the possible analytical tools and indicators for the numerical analysis. Uncertainty quantification tools are then key elements of the assessment framework. We discuss the relevance of and challenges for the development of SA, with a specific focus on applicability in specific decision contexts such as policy option assessment.

Keywords: Sustainability science, Sustainability assessment, Integrated assessment, Boundaries, Policy support, Science-policy interface, Policy option assessment

Pn586ssbc

1. Introduction

Assessing sustainability is increasingly becoming common practice in product, policy, and institutional appraisals. Terms such as "Integrated Assessment" and "Sustainability Assessment"[1] are used to label 'new' approaches to impact assessment that are designed to direct planning and decision-making towards sustainable development (SD) (Hacking and Guthrie, 2008). Examples of current definitions of sustainability assessment are:

- Sustainability assessment is a tool that can help decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable (Devuyst, 2001, p. 9); or
- The aim of sustainability assessment is to ensure that ''plans and activities make an optimal contribution to sustainable development'' (Verheem, 2002).

However, increasing concern has been voiced in the scientific community regarding whether the various available examples of sustainability assessment (SA) are really comprehensive, and able to judge in a robust and reliable way whether new developments "meet the needs of the present without compromising the ability of future generations to meet their own needs" (WCDE 1987). Concerns are mainly related to the intrinsic vagueness of the sustainability concept itself (sustainable development is, like social justice, and so on, a value-laden concept that has many different dimensions and perceptions), and to the capability of addressing environmental, economic and social issues and their interactions with robust and fit-for-purpose measures (Bohringer and Jochem, 2007). Furthermore, a distinction between integrated assessment and SA may be made, and in the present work, we propose how to move from integrated assessment to sustainability assessment.

The fundamental differences are at both the ontological and epistemological levels. Performing a sustainability assessment requires integrating sustainability principles, thresholds and targets in the evaluation, as well as moving from a mere multidisciplinary to inter- and trans-disciplinary approaches.

Therefore, the major challenges for sustainability assessment are related to: the lack of both scientific-based and policy-based boundaries, which are able to define a threshold between what contributes to a sustainable development and what does not; and the capability of performing the co-production of knowledge and solutions in a transdisciplinary setting. As a matter of fact, in common practice, there are no guarantees that the option selected after an SA will contribute to a sustainable development in the sense previously defined. In particular, from a semantic perspective, sustainability assessment should aim at understanding whether the impact on the development of the ecosystem in which we live is connected to a certain element envisaged in the ecosystem itself, subject to our capability to foresee such an impact. As will be discussed in the remainder of the paper, a full understanding of the complex dynamics involved in the introduction of a new policy or product is often beyond our capabilities (at least with the current state of knowledge), especially for what concerns the impacts on social and economic spheres.

This epistemic uncertainty is generating certain scepticism about the use of the sustainability concept, not because of its underlying theory, but mainly due to the intrinsic difficulties involved in measuring it (which, in turn, allows everyone to claim to have followed its basic principles). Hence, there is the renovated urgency of clearly defining "sustainability of what, why and for whom?" (O'Connor, 2007).

---

[1] Other synonyms adopted are: "Triple Bottom Line Assessment", "3E Impact Assessment" [Environmental, Economic, Equity], "Extended Impact Assessment", and "Sustainability Appraisal".

In order to offer guidance, principles for assessment and measurement are beginning to be proposed. What is known as the BellagioSTAMP (Sustainability Assessment and Measurement Principles) represents, in this context, an interesting example of such attempts. It was first developed in 1996, and, was recently broadened and revisited (Pinter et al., 2012). These authors sought to delineate the principles and requirements of robust SA. Unfortunately, most case studies assessing sustainability and adopting the common triple bottom-line approach (TBL) still end up comparing different alternatives on the basis of indicators (more or less) casually[2] chosen from among various alternatives in the three pillars of sustainability (namely economy, environment and society), without deepening the analysis of potential interconnections between the pillars.

In this vein, the present paper tries to sketch a first comprehensive (as far as possible, given the vast literature on this matter) procedural methodology, which aims to overcome vagueness and subjectivity in favour of a transparent, robust and flexible assessment. The methodology is developed in line with the main challenges posed by sustainability science and by the sustainability methods developed in recent years. Transparency in values and in the choice of analytical tools, robustness in the analytical steps, and flexibility in the decision context of application are all discussed as key elements of the framework.

The methodological framework can be used for the assessment of both new and existing policies and measures, as well as for understanding the impact of the production and/or consumption of goods and services, and the efficiency/effectiveness of sustainable management strategies put in place by public bodies and private companies. It considers values and sustainability principles as preliminary choices in the definition of the sustainability framework on which the assessment will be based. In addition, it follows the assessment principles outlined by the research activities connected with BellagioSTAMP. Finally, it tries to translate principles and underlying concepts into the implementation of the analytical tools that will be used for the final sustainability assessment. The role of the various elements of the framework is to make the analyst aware of several possible variables that will influence the final result of his analysis. As a checklist, it aims to ensure that no decision variables have been neglected. The reader will easily appreciate that the methodology proposed here represents a support for day-to-day practice in order to assure completeness, comprehensiveness, and transparency of the assessment. At the same time it makes the procedure for SA as complex as it should be.

The paper is organised as follows: Section 2 provides a brief discussion of the state of the art in sustainability science and assessment, with specific reference to the emerging debate on what the role, scope, and objective of SA should be. In Section 3, the methodology for sustainability assessment is presented and described. Section 4 further specifies how to operationalise the assessment. The concluding section provides the main outcomes of the paper, and proposes some points for further discussion, specifically regarding concerns of the authors on the actual possibility of performing a complete sustainability assessment.

2. State of the Art in Sustainability Science and Assessment

Urgent and complex problems are challenging earth systems and humankind, and are rising as a consequence of human-nature and human-human interactions. There is an increasing concern, regarding the capability of the “normal sciences”, to tackle and provide reasonable and reliable

[2] In using the word “casually” it is not intended that in the available case studies the respective authors did not pay sufficient attention in choosing the different indicators, but that the choices seem more influenced by information availability, rather than by the necessity to represent one of the three pillars (and the sustainability of its evolution)

solutions. The complexity and the multidimensional facets of sustainable development are pushing the scientific community to find new models and paradigms, leading, in recent times, to the emerging field of sustainability science, whose domain was set by seven core questions identified by Kates et al. (2001 and updated by Kates in 2011), and by the conceptualisation of Komiyama and Takeuchi (2006).

Since then, the global scientific awareness of long-term threats to our vulnerable ecosystems has called for the development of a new discipline: sustainability science. Four main definitions of sustainability science can be derived from our review:

- an advanced form of complex system analysis aimed at enhancing the understanding of the coupled human-environment conditions through advanced analytical-descriptive tools (Turner et al., 2003);
- a transformational agenda, according to which "the research community needs to complement its historic role in identifying problems of sustainability with a greater willingness to join up with the development and other communities to work on practical solutions to those problems (Clark and Dickson, 2003, p. 8059);
- sustainability science embodies the scientific possibility of transcending the reductionist analyses of the traditional sciences by means of a holistic approach to problem-solving, based on a systemic understanding of contemporary phenomena, both in the economic and social spheres and in environmental, political, and ecological areas (Osorio et al., 2009);
- sustainability science is a solution-oriented discipline that studies the complex relationship between nature and humankind, conciliating the scientific and social reference paradigms which are mutually influenced, and covering multi temporal and spatial scales. The discipline implies a holistic approach, able to capitalise and integrate sectorial knowledge as well as a variety of epistemic and normative stances and methodologies towards the definition of solutions (Sala et al 2012).

Actually, as a problem- and solution-orientated field, epistemologically, sustainability science is based on the concepts of use-inspired basic research, post-normal and mode-2 science (Stokes, 1997, Funtowicz and Ravetz 1993; Gibbons et al., 1994). The elements underpinning this new discipline and the corresponding research practices are transdisciplinary, community-based, interactive, or participatory approaches (e.g. Jahn, 2008).

Sustainability, from a disciplinary perspective, transcends the subject-object relationship of traditional science and poses a relational element as the study object, in which the spatio-temporal dimension and the contexts for that relationship are included. In this sense, science shows a growing awareness of the emergence of ever-increasing complex challenges in the contemporary world – in which traditional science is increasingly perceived as being incapable of dealing with and providing effective answers (Osorio et al., 2009).

Furthermore, new science-society interactions are crucial, and lead to multiple forms of knowledge and the synthesis of theory and practice intended to resolve pressing societal problems through collaboration among scientists from different academic disciplines and with other stakeholder groups (business, government, civil society) (Sala et al., 2012).

Moreover, the conceptual break introduced by sustainability science has also fascinated a wider audience thanks to the clear objective with which it is coupled: "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCDE, 1987). The powerfulness of this objective has further increased in recent years as the even more frequent economic turbulences and environmental disasters have revealed the fragility of our planet and the shortcomings of a development model that for many years has been blindly considered as fully acceptable.

Therefore, having the ultimate objective of sustainability science clearly in mind, in order to perform a coherent sustainability assessment, according to Sala et al. (2012), the current research challenges call for:

- *adopting a holistic approach* for understanding the dynamic interactions between nature and society, and assessing vulnerability and resilience of complex social-ecological systems;
- *moving from multidisciplinarity, via interdisciplinarity towards transdisciplinarity*. Multidisciplinarity is characterised by the unintegrated application of more than one disciplinary methodology to analyse a topic from different perspectives (Wickson et al., 2006); interdisciplinarity integrates methods, concepts, and theories, transferring them from one discipline to another to achieve a common understanding of complex problems (Wickson et al., 2006), while transdisciplinarity is characterised by (Lang et al., 2012):
    - functional integration of different methodologies and epistemologies;
    - co-production of knowledge through the collaboration and participation of different stakeholders;
    - strong links with the specific social/local context and institutional setting from where sustainability problems originate;
    - inclusion of relevant values and common goods perceptions in the identification of the solutions (subjective and normative dimensions);
- *having a normative function* (the capability to provide direction through visions and goals). Sustainability science addresses the normative question of how coupled human-environment systems would function and look like if they complied with a variety of value-laden goals and objectives. Moreover, it also addresses the strategic and operational questions of what viable transition pathways could be identified for coupled human-environment systems and strategies for finding solutions to sustainability problems (Wiek et al., 2012a);
- *promoting social learning and mutual feedback* (learning through doing and doing through learning) leading to co-production of knowledge with other stakeholder groups such as business, politicians, and society in a common process of problem identification and resolution. (The current debate is often on how far the sustainability science endeavour has fulfilled the claim and promises of its transformational function; see Wiek et al., 2012a, Wiek at al., 2012b));
- *dealing with uncertainties*. Adopting a probabilistic approach for the assessment of scenarios is essential to achieve robust decision making (Funtowicz and Ravetz, 1993).

Unfortunately, these characteristics, although acknowledged by many practitioners in the field, are rarely found in the available empirical examples of SA. As already pointed out in Pope et al. (2004), many examples of SA are "only" examples of integrated assessment that have been "extended to incorporate social and economic considerations as well as environmental ones, reflecting a triple bottom line approach to sustainability". As a result, also noticed by the same authors (Pope et al., 2004), options assessed in this light might also "not result in sustainable practice". Yet the reason for this apparent contradiction lies in the very origins of the SA concept, which basically derives from environmental impact assessment (for public and private projects) and strategic environmental assessment (for policies and programmes) in order to also include social and economic aspects (Pope et al., 2004). However, as clearly pointed out by Pope (2006), this idea immediately legitimates, for example, the trading-off of the environment for economic gain and the perceived social benefits (and, of course, all possible permutations of the three sustainability pillars in this concept). This legitimation is also supported by the weak sustainability perspective (Gutés, 1996) according to which there is full substitutability between human capital (incorporating resources like infrastructure, labour and knowledge) and natural capital (which covers the stock of environmental assets like biodiversity and other ecosystem services). In this light, as reported by Pope (2006), SA is seen by many authors as a potentially "retrograde and dangerous step".

To overcome this criticism, in the present paper, we advocate transparency as the decisive means to acknowledge the richness and complexity of the sustainability concept. In our view, for example, before carrying out an SA, it is necessary to define clearly the sustainability framework, defined as the "rationale and the structure for the integration of concepts, methodologies, methods and tools" (Sala et al., 2012). If an assessment is performed in a weak sustainability framework, the trade-offs are acceptable, but the authors take the responsibility for this assumption. A methodological procedural framework for SA is thus developed and presented here in order to embody the prerequisites previously described, and to overcome the potential criticisms of the approach.

In this light we postulate that the fundamental differences between SA and other integrated assessment methods can be identified at three levels:

- *Ontologically*, as SA calls for comprehensiveness in the assessment and for the integration of the carrying capacity of the systems under assessment (being environmental or socio-economic systems) in order to define boundaries/thresholds of sustainability;
- *Methodologically*, as the mutual feedback and interactions between environmental and socio-economic systems should be modelled and assessed through specific methodologies;
- *Epistemologically*, as the shift to post normal science requires a different perspective concerning the science-policy interface. SA, being value-laden and intimately related to cultural perspectives, has a political character. This calls for a concrete contribution and involvement of stakeholders in all steps of the process.

3. Methodological Framework for Sustainability Assessment

3.1. Architecture

Sustainability science needs to link science to actions. These actions, being policies, planning, or products, need to be evaluated in order to define the degree of sustainability through sustainability assessment (SA). We will first present the architecture of sustainability assessment.

As pointed out, the aim of the present article is to design a conceptual framework that would allow any researcher or practitioner involved in an SA to follow logical, consistent procedural steps. A schematic representation of the methodological framework is presented in Figure 1. The framework encapsulates two main parts: (i) the SA principles; and (ii) the SA procedure. A brief discussion of the different elements is provided below.

3.2. Sustainability assessment principles

Next to the sustainability principles (section 3.3.1.2), there are other principles to be taken into consideration in the assessment. From among the possible alternatives, we have chosen to consider the principles of BellagioSTAMP as they represent the results of a harmonisation among several field experts and they were those most consistent with our ideas. These principles were originally developed by a group of measurement practitioners in 1996, and recently updated in 2012 (Pinter et al., 2012). The definitions provided for the different principles are as follows:

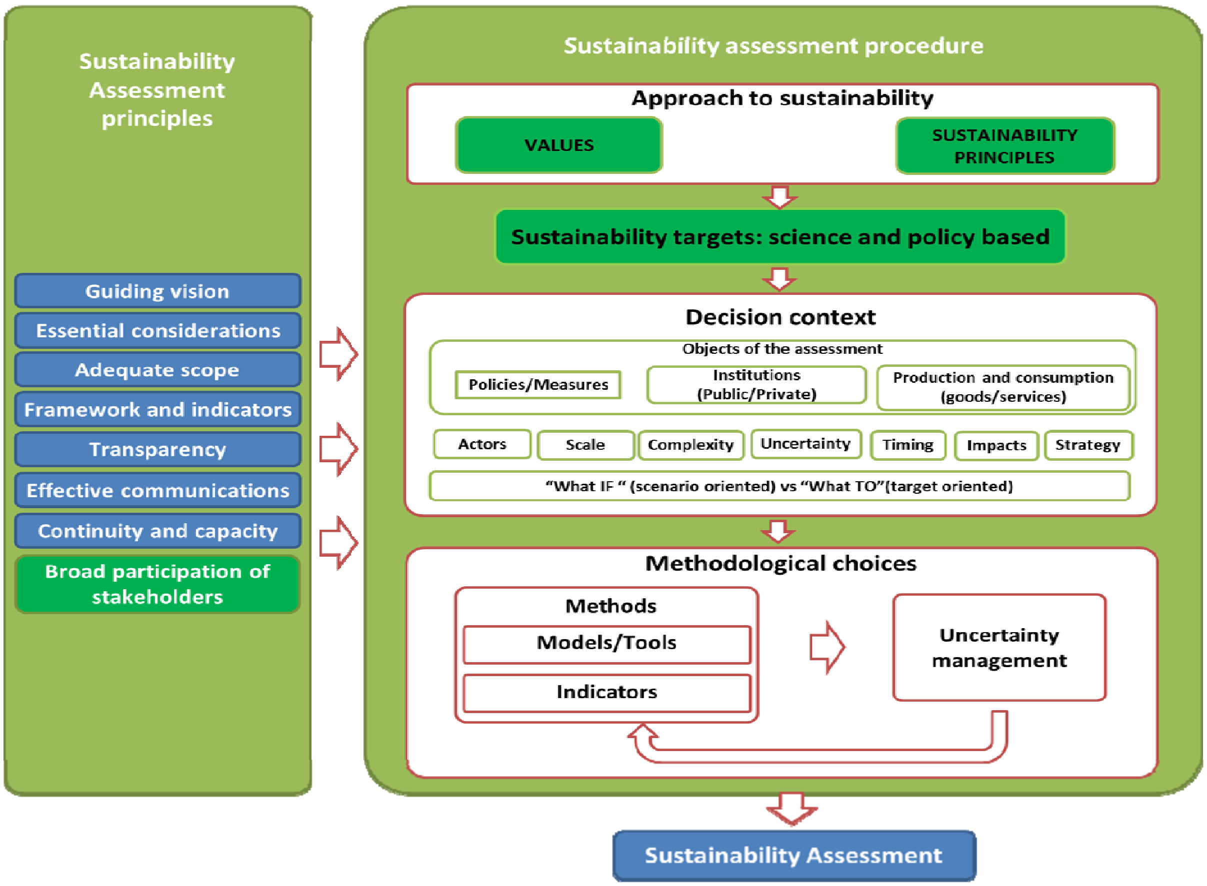


Figure 1. Schematic representation of the conceptual framework for sustainability assessment. Key elements, which distinguish sustainability assessment from integrated assessment, are reported in dark green colour.

1) *Guiding vision*. The assessment of progress towards sustainable development will be guided by the goal of delivering well-being within the capacity of the biosphere in order to sustain it for future generations.
2) *Essential considerations*. The assessment of progress towards sustainable development should consider: the underlying social, economic and environmental system as a whole, and the interactions among its components, including issues related to governance; the dynamics of, and interactions between, current trends and drivers of change; the risks, uncertainties, and activities that can have an impact across boundaries; and the implications for decision making (including trade-offs and synergies).
3) *Adequate scope*. The assessment of progress towards sustainable development will adopt an appropriate time horizon, to capture both short- and long-term effects of current policy decisions and human activities, and an appropriate geographical scope, to capture both their local and their global effects.
4) *Framework and indicators*. SAs are based on: a conceptual framework that identifies the domains for which core indicators have to cover reliable data, projections and models; the most recent data in order to infer trends and build scenarios; standardised measurement methods wherever possible, to ensure comparability. Finally, the comparison of indicator values with targets and benchmarks has to be performed, where possible.

5) *Transparency*. In the context of SAs, data, indicators and results need to be accessible to the public. Choices, assumptions and uncertainties which determine the results of the assessment have to be clearly reported and explained. Data sources and methods, as well as all sources of funding and potential conflicts of interest have to be disclosed.
6) *Effective communications*. In the interests of effective communication and to attract the broadest possible audience and minimise the risk of misuse, SAs should be required to use clear and plain language; to present information in a fair and objective way that helps to build trust; to use innovative visual tools and graphics to aid interpretation and tell a story; and to make data available in as much detail as reliable and practical.
7) *Continuity and capacity*. SAs require that they are complemented by a continuous monitoring phase. Therefore, repeated measurement as well as responsiveness to change are needed. Investments are therefore necessary to develop and maintain adequate capacity (via, for example, continuous learning and improvement).
8) *Broad participation*. To strengthen their legitimacy and relevance, SAs should find appropriate ways to reflect the views of the public while providing active leadership, and to engage early on with users of the assessment so that they best fit the users' needs.

These principles are crucial, because they can very fruitfully guide the practitioner performing the assessment by ensuring that what is performed is not just a simple integrated assessment but an effective SA.

In our opinion, a very specific requirement of sustainability assessment is the stakeholder’s involvement (including the “broad participation” principle). It should be embedded in all steps presented in Figure 1, in a trans-disciplinary setting, leading to a co-production of knowledge from problem definition towards solutions (Sala et al., 2012).

3.3. Sustainability assessment procedure

The SA procedure comprises several steps, based on the definition of: the approach to sustainability, the sustainability targets, the decision context and the methodological choices for the assessment, as presented in Figure 1 at the beginning of this section.

3.3.1. Approach to sustainability

An important input for the SA is the approach to sustainability adopted by the organisation or stakeholder requiring it. As an example, the assessment will be different according to whether sustainability is seen from a weak or strong perspective. In Figure 1, we see the approach to sustainability characterised by two aspects: (a) *values*; and (b) *sustainability principles*.

3.3.1.1. Values

The effectiveness of SA is often highly questioned, in view of the value-based nature of the assumed goal (sustainable development) and because effectiveness itself can be determined on the basis of a number of different theoretical framework without a specific guarantee of sustainable outcomes (Bond et al., 2011). In most cases, the choice of the evaluation tool is made by the analyst(s), without taking into consideration the values of the affected stakeholders. According to Gallopin (2001), a multiplicity of legitimate perspectives is one of the key features of complex systems. This multiplicity of perspectives involves the joint contribution of the different perspectives from which a systemic problematic phenomenon is perceived during the process of solution searching. It requires assuming the different contexts in which the phenomenon can be comprehended. Hence, by choosing an analytical tool, the analyst essentially “subscribes to” and ultimately “enforces” a particular world view as the legitimate yardstick by which to evaluate the sustainability of a particular project (Gasparatos, 2010). No methodology/method/model could avoid being the result of a certain scientific, cultural and political/institutional milieu. Notwithstanding the necessity to have the most objective assessment, a transparent presentation of values behind the assessment is crucial for ensuring credibility and robustness of the sustainability assessment methods (e.g. strong versus weak sustainability, and the clear definition of the guiding vision and perspective).

3.3.1.2. Sustainability principles

The different values are then differently translated and considered by the different contexts requiring the analysis. For example, well-known sustainability principles are: the precautionary principle; irreversibility; regeneration; substitutability; critical loads; the holistic approach; the polluter pays principle; intergenerational equity; good governance (that is, subsidiarity, proportionality and public participation).

In these principles, several elements and several visions can be distinguished. For example, the planetary boundaries indicated in Rockström et al. (2009) may represent important principles that must be respected no matter what the specific cultural and socio-political driven values are. In addition, principles may have different sources and perspectives which also depend on the geographical region in which they are developed (the sustainability principles as they are understood in the U.S., Europe and East-Asia may be considerably different because of the deep cultural peculiarities and differences associated with these areas). Traditional and more recent sources of principles are, for example: Agenda 21 (UN, 1992); the Millennium Development Goal (UN, 2000); the EU Sustainable Development Strategy (CEC, 2001); the EU Flagship policies 2020 (CEC, 2010); the report Resilient People, Resilient Planet: A future worth choosing (UN, 2012); and so on.

Values and sustainability principles define a sustainability framework. As already pointed out, there are different sustainability frameworks. In order to provide the reader with a practical example, we report the different sustainability interpretations outlined in Patterson (2010):

(1) *ecological interpretations* tend to emphasise the ideas of: threshold; the steady state (although this is hotly disputed); carrying capacity; interdependence between ecological processes; and the idea that the socio-economic sub-system is embedded within the global biophysical system;
(2) *economic interpretations* tend to emphasise the idea of social welfare and the external environmental costs associated with economic activity, as well as the principle of intergenerational equity through the use of capital theory;
(3) *thermodynamic and ecological-economic interpretations* accept the essence of many of the ecological interpretations, but go further by situating ecological sustainability in the context of the entropic nature of economic-environmental interactions;
(4) *public policy and planning theory approaches* to sustainability emphasise the social, institutional, economic and environmental aspects of sustainability within a framework that seeks to achieve a “balance” or an “integration” of these factors.

Independently of the interpretation, the sustainability framework described here has to be translated into some sustainability targets, with which the results of the assessment will be compared. It is worth underlining that, in our opinion, there is no reason to talk about SA if no sustainability targets are defined.

The necessity to identify these targets, together with the recognised political character of the SA, prompts several issues. Firstly, one may argue that they might be exogenously identified by an intergovernmental body (like the United Nations), and assigned to the different countries and/or different economic sectors. If supplied with a robust participatory process, this approach should be able to achieve satisfactorily shared results. Another option would be to have the targets assigned at the lower level, endogenously to the procedure: namely, by the individual opinion of the agent who is performing the SA. In this way, the transparency of the procedure is met and the regulator (namely, any actor involved) may act to question the validity and the robustness of the target defined. With this approach, after a transition period, as soon as an increasing number of assessments propose them, targets are likely to be self-standing and self-updating with respect to the evolution of environmental, economic, and socio-cultural trends.

Both approaches have possible benefits but may imply considerable risks. It is premature to propose a solution at this moment. It is more plausible to stimulate a broader discussion on this topic.

3.3.2. Decision context

This phase of the assessment represents the mirror image of the approach to the sustainability of the external input. In particular, the analyst should filter and translate in practical terms the sustainability framework identified by the context of assessment. In this way, all possible fuzzy messages received for the analysis are de-fuzzyfied (translated) into a quantitative decision context. The decision context can be conceptualised in various forms. In Figure 1, we basically acknowledge the approach proposed by Moberg (1999). In particular, the fundamental aspects to be considered are the following: (a) the actor (and therefore the assessment framework must take into consideration the subject of the assessment as defined by the assessment driver); (b) the scale of the assessment; (c) the complexity of the decision; (d) the uncertainty of the decision (here the assessment framework evaluates the first source of uncertainty defined later in section 3.3.3.2); (e) the time horizon in which the impacts are foreseen; (f) the activity affected by the decision (e.g. investment, decommissioning, planning, maintenance, etc.); and (g) the impacts of interest.

An SA can be carried out in several contexts and can have different objectives. It may be used to assess the impact on sustainable development of different policies and measures proposed at the political level, but it can also be used to assess whether a certain company or public institution is contributing to sustainable (or unsustainable) development, and whether the consumption/production of a certain product or service is sustainable or not. In all these cases, the SA can be carried out in a similar fashion, but each case will influence the different phases of the assessment (for instance, in the SA of a certain product, it is likely that a life cycle perspective will be adopted, while this is not necessarily the case for the assessment of certain policies, and, of course, the modelling framework implied will also be different).

In addition, another key issue to be defined in the decision context is the approach adopted to carry out the SA. In decision theory, two main approaches can be considered: the *threshold approach* (sometimes known as the “what to” approach, which identifies targets) and the *scenario planning* (also known as the “what if” approach).

The former approach should be preferred when there are boundaries that, if crossed, can lead to major consequences (Polasky et al., 2011). This is the case, for example, for CO_2 concentration in the atmosphere and climate change. The main risk associated with this approach is that focussing only on thresholds can give the misleading impression that “degradation below the threshold level is safe and improvements beyond it are of no value” (Polasky et al., 2011). In addition, most of the thresholds hide considerable levels of uncertainty that are difficult to quantify, so that relying only on some fixed values may not turn out to be worthwhile. For this reason, any threshold should always be considered together with the level of confidence that has been assumed in its definition (and preferably also its probability distribution).

The latter approach focuses on the identification of different plausible scenarios. Scenarios are a set of possible futures that are evaluated on the basis of different criteria. In SA, scenarios need to be evaluated using criteria pertaining to the three different pillars of sustainability. In this way, it is unlikely that a scenario would be found that outperforms all the others over all criteria adopted (Pareto optimality). For this reason, even with different approaches, in most cases, a single indicator is evaluated as a weighted combination of the criteria (e.g. multi-criteria assessment).

At the end of this phase the analyst needs to have gathered all possible elements in order to identify the best possible framework for undertaking the assessment.

3.3.3. Methodological choices for performing the assessment

The selection of the most appropriate approach has to be evaluated case-by-case, and will influence the final phase consisting of the pure assessment framework.

This is the core of the SA framework. It is composed of different phases:

- identification of the most suitable assessment methodologies (and related methods[3], models, tools, and indicators);
- sensitivity and uncertainty analysis of the assessment framework;
- definition of monitoring strategies to track progress towards sustainability.

We adopted the terminology as in Sala et al. (2012) acknowledging a hierarchically different role of each element. In particular, the *framework* is the rationale and structure for the integration of concepts, methodologies, methods and tools; the *methodology* is a collection of individual characterisation methods, which together address the different environmental, economic and social issues and the associated effect/impact; the *method* is a set of models, tools and indicators that enable the calculation of the values of indicators for a certain impact category; the *model* is the mathematical description of the system and it is used to calculate a particular indicator of the impact of environmental/social/economic interventions; the *tool* is the software, application, database supporting the analysis done by adopting a specific method and the related models; and the *indicator* is a parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon, with a significance extending beyond that directly associated with its value (OECD, 2003). The parameter could be quantitative, semi-quantitative, or qualitative and is derived from a model, often through a tool.

In the following, we describe the principles for the identification of the most suitable methodologies and of sensitivity and uncertainty analysis. Since it will involve all phases of the assessment, a specific section to briefly describe the principles of the stakeholders' involvement is also provided. For what concerns the definition of monitoring strategies, in line with the continuity and capacity assessment principle, we argue that an SA should also identify all possible indicators that need to be monitored to assess progress towards the objectives of the study.

3.3.3.1. Identification of the most suitable methodologies

A good categorisation of available methodologies and related methods is of paramount importance in order to identify the most suitable means for the assessment. A plethora of indicators, methods/methodologies and models for SA have been developed over the last 30 years. The majority of

[3] In literature the terminology is not consistent and harmonised, e.g. , adopting "methods" (Thabrew et al., 2009; Patterson, 2010, Jeswani et al., 2010), "tools" (Ness et al., 2007; Finnveden and Moberg, 2005, Kissinger and Rees, 2010), "approaches" (Gasparatos et al., 2008; Hacking and Gunthrie, 2008), "indices" (Mayer, 2008); and "methodologies" (Singh et al. 2011) to indicate the same subject.

these were applications of approaches developed in other contexts, and then transposed within SA. In the literature, the methods were extensively reviewed in order to identify specific criteria for their categorisation. These criteria were based on a specific definition of SA, and on a clear definition of intrinsic ethical and cultural inherent values. In our research, we selected a number of papers in order to compile a list of criteria for discrimination of whether a method is capable to fulfil requirements of a robust sustainability assessment.

The papers were chosen selecting those which: reviewed existing SA methods, comparing and contrasting existing SA methods in order to highlight critical areas and suggestions; and defined features and peculiarities of SA methods, provided list recommendations for improving the SD-directedness of assessments. The full list of features and criteria assessed by selected papers (Finnveden and Moberg, 2005; Gasparatos et al., 2008; Ness et al., 2007; Hacking and Guthrie, 2008; Mayer, 2008; Thabrew et al., 2009; Singh et al., 2011; Kissinger et al., 2011; Jeswani et al., 2010; Patterson, 2010) is reported in SA, covering ontological, epistemological and methodological aspects.

This meta-review highlighted that among the current adopted methods, only a few were developed specifically for application in sustainability assessment, reductionism is still the dominant paradigm for sustainability assessment (Gasparatos, 2010), and few methods are comprehensive in dealing with a cross-pillar integrated assessment.

On the basis of the above review, we have elaborated the categorisation scheme reported in Figure 2, representing a spectrum of criteria for assessing the capability of methods to address sustainability.

Even if presented in the abovementioned papers, the features of methods, models, indices and indicators that are purely methodological are not discussed here. In fact, methodological elements are crucial for the robustness of the assessment, but they are not peculiar from sustainability assessment methods as they may apply to all scientific context and methods. For instance, as discussed by Mayer (2008), policy decisions can be ineffective or even counterproductive if they do not consider factors which influence index behaviour: the scale of the available data and choice of system boundaries; the inclusion, transformation, and weighting of indicator data; and the aggregation method used. This may also apply to methods developed outside SA and applicable in a general context whereas there are other aspects explicitly developed for SA.

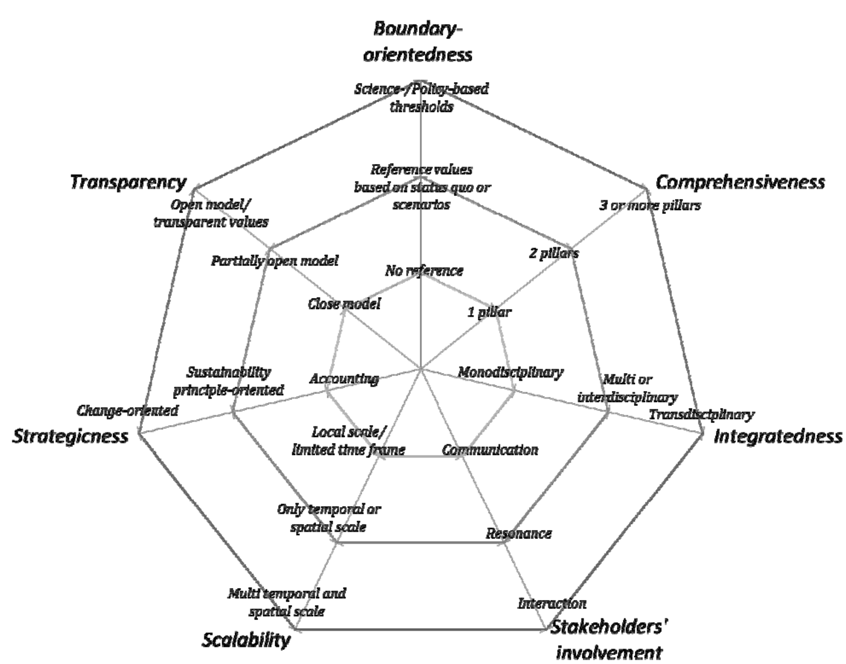
Here, we report criteria that are strictly related to the SD-orientation of the methodology itself, such as:

- the boundary-orientatedness (starting from no reference adopted, up to combining science-based and policy based thresholds)
- the comprehensiveness (from covering one pillar up to three or more pillars)
- the integratedness (from a mono-disciplinary, sectorial approach up to a trans-disciplinary, inter-sectorial and participated approach)
- stakeholders' involvement (from mere communication, up to close interaction in all phases of the assessment)
- scalability (from local, specific and with limited time frame approaches, up to methods capable to deal with multi temporal and multiscale aspects)
- strategicness (from mere accounting methods, up to methods that already integrated sustainability principles – e.g. life cycle thinking – and true solution orientated/change orientated methods)
- transparency (from close model to open model in which values are also transparently reported)

Specifically, for the integratedness, in the scheme shown in Figure 3, the relative position of common methods is reported as examples. For the purpose of our SA framework, we made a categorisation of methods based on: addressing one or multiple pillars; being integrated within one pillar to ensure the comprehensiveness of the assessment (e.g. the carbon footprint is a procedure for measuring the amount of greenhouse gasses, but cannot be considered to be as comprehensive as Life Cycle Assessment, which covers over 12 different impact categories, ranging from climate change to eutrophication, toxicity impact, and so on, EC-JRC 2011); being integrated, covering the three pillars (e.g. a dashboard of sustainability).

More specifically, following the principle of Figures 2 and 3, we have outlined here three approaches to the identification and selection of suitable methodologies and related methods for sustainability assessment, to be applied in the specific case/context:

- *the reductionistic approach*, in which the results of several models and tools are combined, covering the three pillars;
- *the holistic approach*, in which methods and models specifically developed for SA are chosen, in order to assess the emergent properties of the socio-ecological system affecting the problem/issue being evaluated;
- *the combined approach*, in which in the framework of the holistic approach to the evaluation, the reductionistic model and methods are used to delve into some specific theme/issue within the assessment.



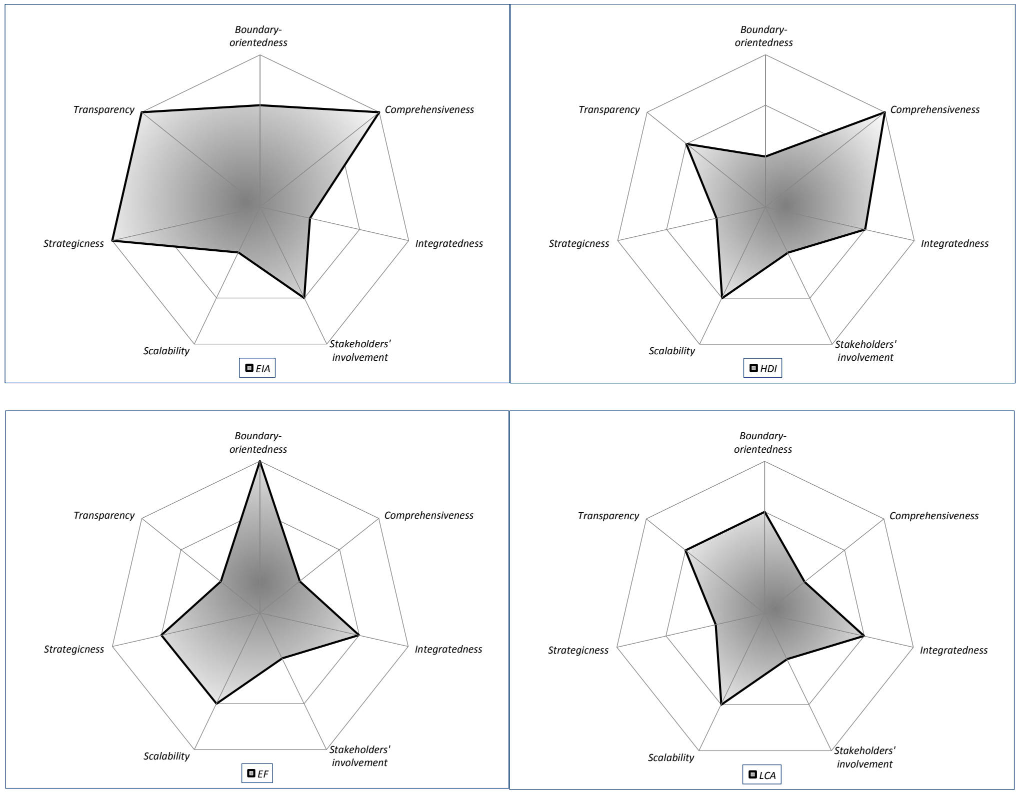


Figure 2. Spectrum of criteria for assessing the capability of methods to address sustainability and an example of the evaluation of four methods (EIA – Environmental Impact Assessment; HDI – Human Development Index; EF- Environmental Footprint; LCA- Life Cycle Assessment)

In the context of SA, the analyst often needs to combine different methods, models and indicators. The main challenges that we identified in the combination/integration of these SA methods are:

- How to combine different tools/methods (from concepts to data), assuming that, from multidisciplinary and interdisciplinary perspectives, such a combination might be feasible and meaningful, and the results robust (see, e.g. Castellani and Sala, 2012);
- How to set hierarchically-different tools to assess and measure the emergent properties of the socio-ecological systems at hand (specifically developed for tackling sustainability problems);
- How to address uncertainty propagation;
- How to assure the Galilean replicability/comparability of the evaluation, especially considering that SA implies dealing with complexity and non-linearity, presenting a dynamic variation of the system rather than a linear relationship of a cause-effect type (Gallopin, 2001);
- How to ensure transparency.

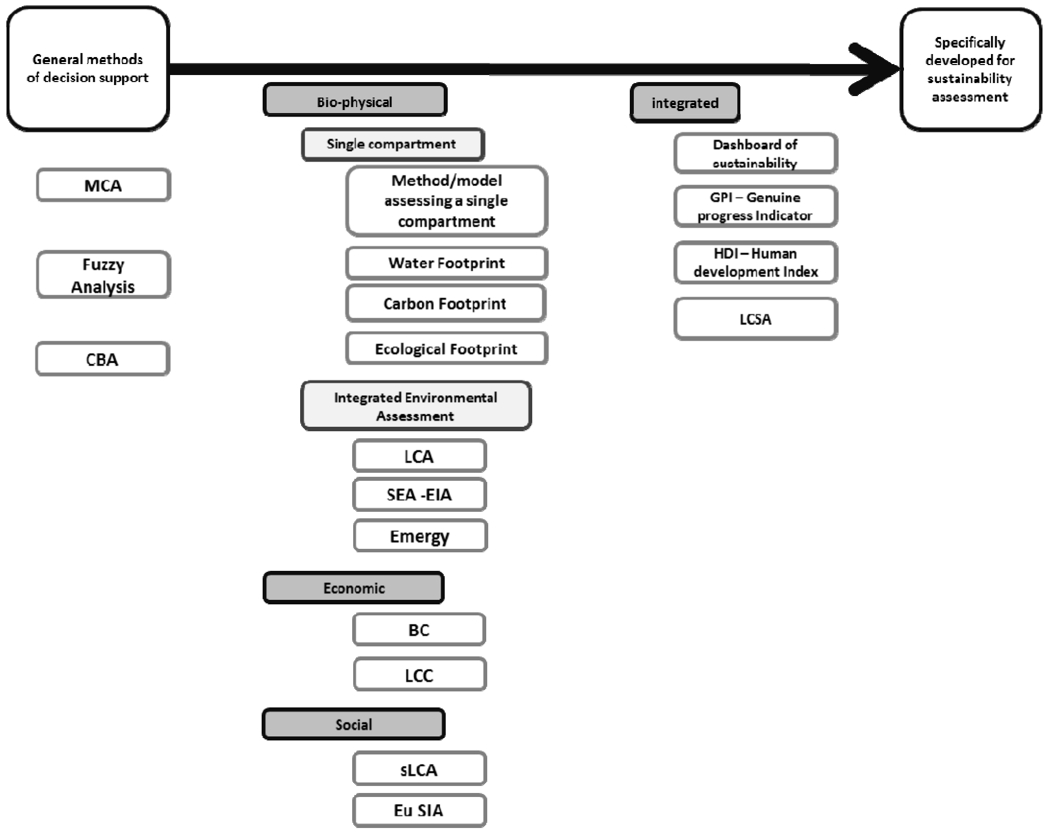


Figure 3. Categorisation scheme for the integratedness of sustainability assessment methodologies (MCA – Multi-Criteria Analysis; CBA – Cost Benefit Analysis; EIA – Environmental Impact Assessment; SEA – Strategic Environmental Assessment; LCA – Life Cycle Assessment; LCC – Life Cycle Costing; sLCA – Social LCA; EuSIA – Eu Social Impact Assessment; LCSA – Life Cycle Sustainability Assessment).

3.3.3.2. Dealing with uncertainty in sustainability assessment

For both the definition of the thresholds and the appraisal of the different scenarios, a sophisticated analysis is required. Regardless of whether a method adopts modelling/simulation-based approaches or experience-based approaches (e.g. by means of time series analysis or structural/morphological analyses), it requires an in-depth understanding of how the world behaves, especially in terms of reaction to the pressure imposed by society. This is even more significant, as we consider the world in which we live as a complex system, involving many sub-systems closely inter-related with each other. In this context, the widely adopted *ceteris paribus* condition for modelling many physical systems can hardly hold (Nijkamp, 2007), and uncertainties rise as soon as we try to understand the system (Saltelli et al., 2008).

However, sometimes uncertainty is used to hide or neglect a problem. As an exemplification, we may describe what happened with climate change. The climate change issue was neglected for years before being really considered. Many sources of uncertainties do indeed exist, such as uncertainty about the likelihood of adverse effects; uncertainty about the consequences of change; uncertainty about the speed of changes; uncertainty about discontinuities; uncertainty about the effectiveness of policy instruments and so on. Focussing attention on the possible sources of uncertainty has been the way to delay policies needed to reduce greenhouse gas emissions (Hansen, 2009). It is straightforward that, in this case, all sources of uncertainty arise from the attempt to model several complex processes, such as the climate response to natural and anthropogenic forces and its impact on society, often mixed in a complex way.

The climate change example is useful to understand how identifying and dealing with the different sources of uncertainty that may arise in SA is important to increase the robustness of the assessment itself. Otherwise, there is the risk of depriving the concept of sustainability assessment of any practical utility. Uncertainty is, indeed, a big issue, especially for policy makers. It can confuse them, but it can be made policy-relevant if the results are translated into the likelihood that policy targets will be met. Policy makers, therefore, have to choose either to accept the risks, or to take actions that increase the certainty that targets will be met. Basically there are two types of policy risks: (i) doing too much; or (ii) doing too little (and being confronted later with irreversible environmental problems). The acceptance of the different types of policy risks will depend on the preference of the politicians and the priorities they give to environmental, social and economic stakes. The careful politician will easily realise that policies can be made more robust when risks are acknowledged and adaptations are made to minimise the risks (or to define a strategy on how to respond if risks really occur). This issue is analysed in more detail in Huesemann (2002).

There are different ways of dealing with uncertainties and a thorough description is beyond the scope of the present work. The interested reader is referred to Boschetti (2011, again on climate change)or to the framework defined by de Rocquigny et al. (2008). . Furthermore, for an additional discussion on the risks connected with the lack of an uncertainty management, the reader is referred to the work of Pappenberger and Beven (2006).

3.3.3.3. Stakeholder's involvement

According to Thabrew et al. (2009), the following criteria may be considered suitable for performing an SA, considering that methodological choices are not only related to the stakeholders' acceptance but also to the stakeholders' potential involvement in the assessment process: (i) allow for stakeholder interaction at all stages of the process; (ii) promote consensus building for joint projects; (iii) support stakeholders to have transparent access to information so that they can examine the assumptions made and the projected outcomes of decisions; (iv) enhance the communication of results and impacts to the stakeholders in a clear and easy way. Examples of stakeholders' involvement in the different steps of decision making in the context of sustainability are: setting sustainability objectives with stakeholders in mid-term planning at a local scale (e.g. Castellani and Sala, 2009); integrating stakeholders' requirements in technology sustainability assessment (e.g. Sala and Castellani, 2011); and involving supply chain stakeholders in an eco-innovation strategy (Nakano and Hirao, 2011) or in project development and assessment (Narain Mathur et al., 2008).

The stakeholder involvement has, therefore, to be seen as an important means to make the whole assessment process more effective and contribute to the attainment of a consensus. New technologies are also opening new perspectives in stakeholder consultation, for example, by providing fast and effective visualisation tools which are able to show the effect of the assessed options.

4. Conclusions and Discussion

In the literature, a broad range of different appraisal processes is described under the heading of sustainability assessment (SA). Nevertheless, current SA practices need a robust framework to overcome concerns recognised in the scientific community regarding whether the various available examples of assessment are really comprehensive and robust, moving from integrated assessment towards an SA. Increasing comprehensiveness and robustness of assessment may fulfil the "transformational" role request to sustainability science. Hence, SA could be seen as leverage for effectively promoting sustainability and not only for evaluating its progress and/or comparing options. In this context, the aim of our methodological framework is not to define an 'ideal' SA methodology but to define key steps as minimum requirements that underpin a comprehensive SA, in which the ontological, epistemological and methodological foundations of sustainability science are recognised, therefore: sustainability is assessed by considering science-based and/or policy-based thresholds; transparency is ensured by reporting background values; trans-disciplinarity informs the appraisal through the co-production of knowledge with stakeholders (in terms of problem definition and solution); and credibility is reinforced through the adoption of robust uncertainty and sensitivity assessment tools.

This may also help to map out the steps forward. Considering that SA has to fulfil at least three main features of sustainability science: interdisciplinarity; its foundation on a holistic perception of reality; and collaboration in scientific research; several challenges have still to be tackled. The following issues are, in our opinion, of paramount relevance:

- Developing methodologies and related methods and models able to move from multidisciplinarity and interdisciplinarity towards transdisciplinarity and holism, in order to identify the emergent properties related to sustainability problems;
- Accounting for multi-geographical and temporal scales ranging from local to global issues (Kissinger et al., 2011), and allowing the development of backcasting and forecasting scenarios;
- Being aware that many issues in the integration of methods and models are still open questions for the research community, especially regarding the paradox of seeking replicability and comparability while dealing with extreme complexity and non-linearities in the assessment, leading to what is referred to as "irreducible uncertainty" (Gallopin, 2001);
- Developing suitable procedures and methods for broadening and better targeting stakeholders' involvement and commitment across the procedure, moving from consultation towards co-production of knowledge and co-responsibilisation;
- Evolving and clarifying the goals of the integrated assessment (from avoiding negative impacts), to proactively enhancing positive impacts. This implies incorporating sustainability goals, moving from the comparative/analysis-orientated approach to a much broader solution-orientated approach and scope.

The proposed methodological framework for SA presented in this study is a beginning towards tackling the above-mentioned critical issues. An effective evolution of the methodology needs a broader involvement of the three communities mentioned by Pinter et al. (2012, p. 26): (i) the communities involved in developing alternative metric systems; (ii) the communities focused on integrated assessment and reporting; and (iii) those practising project or policy-focused evaluation".

On the basis of the meta-review of methods presented in Section 3.3.3.1, for the first community (i) involved in developing methods, developers need to consider which ontological, epistemological, and methodological aspects have to be covered by existing and new methods that handle SA (Sala et al., 2012). The second (ii) and the third (iii) communities are at the science-policy interface, and are broadly involved in the selection of adequate methods, models and indicators, and in the transparent reporting of assumptions and uncertainties. Only the co-production of knowledge within (at least) these three communities could support relevant progress in SA and, to a greater extent, in sustainability mainstreaming.

In section 2 we acknowledged that the fundamental differences between SA and other integrated assessment methods could be identified at three levels, namely ontological, methodological, and epistemological, towards the need for capturing complexity while ensuring transparency, comprehensiveness, completeness, and legitimacy.

Finally, the recognised political character of SA opens the delicate issue concerning who may be really entitled to undertake it. Indeed, before any actor starts to assess the effect of a certain policy, product or body on sustainable development, the necessity to identify clear and well-founded targets may delay this practice. The authors cannot yet give a clear unambiguous clue on this issue. It is plausible, however, that the identification of targets should not necessarily follow a top-down approach, but, on the contrary, should come from the bottom (in order to make the process for their identification and update more rapid and natural) and should be supported by a widely shared process involving all types of stakeholders.

References

Bohringer, C., Jochem, P.E.P. (2007). Measuring the immeasurable – A survey of sustainability indices. *Ecological Economics*, vol. 63, pp. 1-8

Bond, A.J., Dockerty, T., Lovett, A., Riche, A. B., Haughton, A.J., Bohan, D.A., Sage, R.B., Shield, I.F., Finch, J.W., Turner, M.M., Karp, A. (2011). Learning How to Deal with Values, Frames and Governance in Sustainability Appraisal. *Regional Studies*, vol. 45(8), pp. 1157-1170

Boschetti, F. (2011). A graphical representation of uncertainty in complex decision making. *Emergence: Complexity and Organization*, vol. 13(1-2), pp. 146-166

Castellani, V., Sala, S. (2009). Sustainable Performance Index for tourism policy development. *Tourism Management*, vol. 31, pp. 871-880

Castellani, V., Sala, S. (2012). Ecological Footprint and Life Cycle Assessment in the sustainability assessment of tourism activities. *Ecological Indicators*, vol. 16, pp. 135-147

CEC (Commission of the European Communities) (2001). A sustainable Europe for a better world: A European strategy for Sustainable Development" COM(2001) 264 final

CEC (Commission of the European Communities) (2010). Europe 2020. A strategy for smart, sustainable and inclusive growth. Communication from the Commission COM (2010) 2020 final

Clark, W.C., Dickson, N.M. (2003). Sustainability science: The emerging research program. *Proceedings of the US National Academy of Science*, vol. 100, pp. 8059-8061.

de Rocquigny, E., Devictor, N., Tarantola S. (eds.) (2008). *Uncertainty in industrial practice. A guide to quanti- tative uncertainty management.* Chichester: Wiley.

Devuyst, D. (2001). *How green is the city? Sustainability assessment and the management of urban environments*. New York: Columbia University Press, p. 457

EC-JRC (2011). Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in European context. ILCD Handbook - International Reference Life Cycle Data System, European Union EUR24571EN. ISBN 978-92-79-17451-3. Available at http://lct.jrc.ec.europa.eu

Finnveden, G., Moberg, A. (2005). Environmental systems analysis tools- an overview. *Journal of Cleaner Production*, vol. 13, pp. 1165-1173

Funtowicz, S.O., Ravetz, J.R. (1993). Science for the post-normal age. *Futures*, vol. 25, pp. 739-755

Gallopin, G. (2001). Science and technology, sustainability and sustainable development. ECLAC, LC/R.2081. p. 30.

Gasparatos, A., El-Haram, M., Horner, M. (2008). A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment*, vol. 28, pp. 286–311

Gasparatos, A. (2010). Embedded values sytems in sustainability assessment tools and their implications. *Journal of Environmental Management*, vol. 91, pp. 1613-1622

Gibbons, M., Limoges, M., Nowotny, C., Schwartzman, H., Scott, S., Trow, M. (1994). *The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies*. (1st ed). London; Thousand Oaks, pp. 179

Gutes, M.C. (1996). Commentary: The Concept of Weak Sustainability. *Ecological Economics*, vol. 17, pp. 147-156.

Hacking, T., Guthrie, P. (2008). A framework for clarifying the meaning of triple bottom-line, integrated and sustainability assessment. *Environmental Impact Assessment Review*, vol. 28(2–3), pp. 73–89

Hansen, J. (2009). Storms of my grandchildren. Bloomsbury USA. ISBN-13: 978-1608192007

Huesemann, M.H. (2002). The inherent biases in environmental research and their effects on public policy. *Futures*, vol. 34, pp. 621-633

Jahn, T. (2008). Transdisciplinarity in the practice of research. In: Bergmann M, Schramm E (eds) *Transdisziplinare Forschung: Integrative Forschungsprozesse verstehen und bewerten*. Campus Verlag, Frankfurt/Main, Germany, pp. 21–37

Jeswani, H.K., Azapagic, A., Schepelmann, P., Ritthoff, M. (2010). Options for broadening and deepening the LCA approaches. *Journal of Cleaner Production*, vol. 18, pp. 120-127

Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grubler, A., Huntley, B., Jager, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore, B., O'Riordan, T., Svedin, U. (2001). Environment and development: sustainability science. *Science*, vol. 292, pp. 641–642

Kates, R.W. (2011). What kind of science is sustainability science? *Proceedings of the US National Academy of Science*, vol. 108(49), pp. 19449-19450

Kissinger, M., Rees, W.E., Timmer, V. (2011). Interregional sustainability: governance and policy in an ecologically interdependent world. *Environmental Science & Policy,* vol. 14(8), pp. 965-976

Komiyama, H., Takeuchi, K. (2006). Sustainability science: building a new discipline. *Sustainability Science*, vol. 1, pp. 1–6

Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M. and Christopher, J., Thomas, C.J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, vol. 7(1), pp. 25-43

Mayer, A.L. (2008). Strengths and weaknesses of common sustainability indices for multidimensional systems. *Environmental International*, vol. 34, pp. 277–291

Moberg, A. (1999). Environmental systems analytical tools e differences and similarities including a brief case study on heat production using ecological footprint, MIPS, LCA and exergy analysis. M.Sc. thesis, Systems Ecology, Stockholm University, Stockholm

Narain Mathur, V., Price, A.D.F., Austin, S. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, vol. 26(6), pp. 601-609

Nakano, K., Hirao, M. (2011). Collaborative activity with business partners for improvement of product environmental performance using LCA. *Journal of Cleaner Production*, vol. 19(11), pp. 1189-1197

Ness, E., Piirsalu, U., Anderberg, S., Olsson, L. (2007). Categorising tools for sustainability assessment. *Ecological Economics*, vol. 60, pp. 498–508

Nijkamp, P. (2007). Ceteris paribus, spatial complexity and spatial equilibrium. An interpretative perspective. *Regional Science and Urban Economics*, vol. 37, pp. 509–516

OECD (2003). OECD Environmental Indicators – Development, Measurement and Use. Reference Paper, Paris.

Osorio, L.A.R., Lobato, M.O., Del Castillo, X.Á. (2009). An epistemology for sustainability science: a proposal for the study of the health/disease phenomenon. *International Journal for Sustainable Development World*, vol. 16(1), pp. 48-60

O'Connor, M. (2007). Paradigm for sustainability assessment: Inventory of Costs and Benefist versus representative diversity of indicators. Background paper in support of the United Nations System of Environmental-Economic Accounts (SEEA) 2010 Reform Process

Pappenberger, F., Beven, K.J. (2006). Ignorance is bliss: Or seven reasons not to use uncertainty analysis. *Water Resources Research*, vol. 42(5), art. no. W05302

Patterson, M. (2010). Is there more in common than we think? Convergence of Ecological Footprinting, emergy analysis, Life cycle assessment and other methods of sustainability assessment. In: *Proceedings of ISEE 2010 conference "Advancing sustainability in time of crisis"*, retrieved from http://www.isee2010.org/full_papers.php?level=0&cat=speaker&subcat=p, accessed February 2012

Pinter, L., Hardi, P., Martinuzzi, A., Hall, J. (2012). Bellagio STAMP: Principles for sustainability assessment and measurement. *Ecological Indicators*, vol. 17, pp. 20–28

Polasky, S., Carpenter, S.R., Folke, C., Keeler, B. (2011). Decision-making under great uncertainty: Environmental management in an era of global change. *Trends in Ecology and Evolution*, vol. 26(8), pp. 398-404

Pope, J., Annandale, D., Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Impact Assessment and Project Appraisal*, vol. 23(4), pp. 293-302

Pope, J. (2006). Editorial: What's so special about sustainability assessment? *Journal of Environmental Assessment Policy and Management*, vol. 8(3)

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, vol. 14(2), p. 32

Rood, E.P., Telionis, T.P. (1991). Editorial on Experimental Uncertainty. *Journal of Fluids Engineering*. Available at http://www.usbr.gov/pmts/hydraulics_lab/professional/uncertainty/ annotated _bibliography_files/Experimental%20Uncertainty.pdf

Sala, S., Castellani, V. (2011). Technology sustainability assessment to support decision making on energy production at local scale. *International Journal of Sustainable Development and Planning*, vol 6(3), pp. 251-220

Sala, S., Farioli, F., Zamagni, A. (2012). Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment (Part I). *International Journal of LCA*, doi10.1007/s11367-012-0508-6

Saltelli, A., Ratto, M., Anres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., Tarantola, S. (2008). *Global Sensitivity Analysis – The Primer*. Wiley, Chichester.

Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K. (2011). An overview of sustainability assessment methodologies. *Ecological Indicators*, vol. 9(2), pp. 89-112

Stokes, D.E. (1997). Pasteur's Quadrant: Basic Science and Technological Innovation. Washington, DC: Brookings Institution Press, pp180

Sverdrup, H.U., Ragnarsdottir, K.V. (2011). Challenging the planetary boundaries II: Assessing the sustainable global population and phosphate supply, using a systems dynamics assessment model. *Applied Geochemistry* 26(SUPPL.), pp. S307-S310

Thabrew, L., Wiek, A., Ries, R. (2009). Environmental Decision Making in Multi-stakeholder Contexts: Applicability of Life Cycle Thinking in Development Planning and Implementation. *Journal of Cleaner Production*, vol. 17(1), pp. 67-76

Turner II, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the US National Academy of Science*, vol. 100, pp. 8074–8079

UN (1992). Agenda 21. http://www.un.org/esa/dsd/agenda21/res_agenda21_00.shtml (accessed March 2012)

UN (2000). Millennium Development Goals. http://www.un.org/millenniumgoals/ (accessed March 2012)

UN (2012). United Nations Secretary-General's High-level Panel on Global Sustainability. Resilient People, Resilient Planet: A future worth choosing. New York: United Nations.

van der Sluijs, J.P., Risbey, J.S., Kloprogge, P., Ravetz, J.R., Funtowicz, S.O., Corral Quintana, S., Guimaraes Pereira, A., De Marchi, B., Petersen, A.C., Janssen, P.H.M., Hoppe, R., Huijs, S.W.F. (2003). RIVM/MNP Guidance for Uncertainty Assessment and Communication - Detailed Guidance. Utrecht University. ISBN 90-393-3536-2. Available at http://www.nusap.net/downloads/detailedguidance.pdf

van Der Sluijs, J.P., Craye, M., Funtowicz, S., Kloprogge, P., Ravetz, J., Risbey, J. (2005). Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: The NUSAP system. *Risk Analysis*, vol. 25(2), pp. 481-492

Verheem, R. (2002). Recommendations for Sustainability Assessment in the Netherlands. In Commission for EIA. Environmental Impact Assessment in the Netherlands. Views from the Commission for EIA in 2002. The Netherlands

WCDE (World Commission on Environment and Development). (1987). Our common future. Oxford University Press. Oxford

Wickson, F., Carew, A.L., Russell, A.W. (2006). Transdisciplinary research: characteristics, quandaries and quality. *Futures*, vol. 38, pp. 1046-1059

Wiek, A., Ness, B., Schweizer-Ries, P., Brand, F., Farioli, F. (2012a) From complex systems thinking to transformational change: A comparative study on the epistemological and methodological challenges in sustainability science projects. *Sustainability Science*, vol. 7(s1), pp. 5-24

Wiek, A., Farioli, F., Fukushi, K., Yarime, M. (2012b). Sustainability science: bridging the gap between science and society. *Sustainability Science*, vol. 7(s1),pp. 1-4

Annex A. A Meta-Overview

In Table A1, we present the studies selected for the qualitative meta-analysis of SA methods. The reported studies include the main SA features assessed.

Table A1. Criteria used in the reviewed papers to categorise sustainability assessment methodologies, methods, indicators and tools

Sustainability aspects	Criteria for the assessment	Interaction	Reference[4]
Ontology	Subject of the assessment	Product, plan, policies, etc.	[1][9][10]
	Sustainability indices domain (scope of measurement)		[7]
	Capability of taking the three pillars into account (comprehensiveness)		[2][3][4][9]
	Level of integration among pillars (integratedness)		[3][4][5][9]
	Kinds of impact covered (use of resources, environmental impact and/or economic aspects)		[1]
	Capability of addressing indirect inputs and effects		[10]
	Scenario development		[2]
	System boundaries	The focus/perspective is broad and forward-looking ('strategicness')	[4]
		System-wide impacts vs narrower-site impacts	[10]
	Accounting vs change-orientated		[1]
Epistemology	Capability to communicate to stakeholder or to multi-stakeholders' interaction	Communication	[2]
		Interaction	[6]
		Resonance/public perception	[10]
Methodology	Analytical vs procedural tools		[1][9]
	Aggregation method	Bottom-up: sums, averages, and ratios vs Bottom-up: Principal Component Analysis, regression, and information theory	[5]
		Top-down: carrying capacity/accounting	[7]
	System boundaries, data inclusion, normalisation and weighting; Unidimensional/multidimensional; Methodological rigor		[5][10]
	Strategy, techniques/methods employed for construction of index, such as, quantitative/qualitative, subjective/objective, cardinal/ordinal		[7]

[4]Notes: [1] Finnveden and Moberg, 2005; [2] Gasparatos et al., 2008; [3] Ness et al., 2007; [4] Hacking and Guthrie, 2008; [5] Mayer, 2008; [6] Thabrew et al., 2009; [7] Singh et al., 2009; [8] Kissinger et al. , 2010; [9] Jeswani et al., 2010; [10] Patterson, 2010.

	Metrics adopted	Scaling (measured in an absolute or relative manner)	[7]
		Monetary vs bio-physical accounting	[2]
	Data availability		[7]
	Flexibility	Flexibility of the indicator to allow change, purpose, method and comparative application	[7]
		Standardisation level	[10]
	Transparency	Clarity and simplicity in its content, purpose, method, comparative application, and focus	[7]
	Spatial/temporal issues	Forecasting/backcasting; to act retrospectively or prospectively	[2][3]
		Short- vs long-term perspective	[3]
		Scaling measure across space ('cross-section') or time ('time-series')	[7]
		Quantifying, analysing, and modelling interregional linkages	[8]
		Global vs local	[3]

2009-1	Boriana Rukanova Rolf T. Wignand Yao-Hua Tan	From national to supranational government inter-organizational systems: An extended typology, 33 p.
2009-2	Marc D. Bahlmann Marleen H. Huysman Tom Elfring Peter Groenewegen	Global Pipelines or global buzz? A micro-level approach towards the knowledge-based view of clusters, 33 p.
2009-3	Julie E. Ferguson Marleen H. Huysman	Between ambition and approach: Towards sustainable knowledge management in development organizations, 33 p.
2009-4	Mark G. Leijsen	Why empirical cost functions get scale economies wrong, 11 p.
2009-5	Peter Nijkamp Galit Cohen-Blankshtain	The importance of ICT for cities: e-governance and cyber perceptions, 14 p.
2009-6	Eric de Noronha Vaz Mário Caetano Peter Nijkamp	Trapped between antiquity and urbanism. A multi-criteria assessment model of the greater Cairo metropolitan area, 22 p.
2009-7	Eric de Noronha Vaz Teresa de Noronha Vaz Peter Nijkamp	Spatial analysis for policy evaluation of the rural world: Portuguese agriculture in the last decade, 16 p.
2009-8	Teresa de Noronha Vaz Peter Nijkamp	Multitasking in the rural world: Technological change and sustainability, 20 p.
2009-9	Maria Teresa Borzacchiello Vincenzo Torrieri Peter Nijkamp	An operational information systems architecture for assessing sustainable transportation planning: Principles and design, 17 p.
2009-10	Vincenzo Del Giudice Pierfrancesco De Paola Francesca Torrieri Francesca Pagliari Peter Nijkamp	A decision support system for real estate investment choice, 16 p.
2009-11	Miruna Mazurencu Marinescu Peter Nijkamp	IT companies in rough seas: Predictive factors for bankruptcy risk in Romania, 13 p.
2009-12	Boriana Rukanova Helle Zinner Hendriksen Eveline van Stijn Yao-Hua Tan	Bringing is innovation in a highly-regulated environment: A collective action perspective, 33 p.
2009-13	Patricia van Hemert Peter Nijkamp Jolanda Verbraak	Evaluating social science and humanities knowledge production: an exploratory analysis of dynamics in science systems, 20 p.

2009-14	Roberto Patuelli Aura Reggiani Peter Nijkamp Norbert Schanne	Neural networks for cross-sectional employment forecasts: A comparison of model specifications for Germany, 15 p.
2009-15	André de Waal Karima Kourtit Peter Nijkamp	The relationship between the level of completeness of a strategic performance management system and perceived advantages and disadvantages, 19 p.
2009-16	Vincenzo Punzo Vincenzo Torrieri Maria Teresa Borzacchiello Biagio Ciuffo Peter Nijkamp	Modelling intermodal re-balance and integration: planning a sub-lagoon tube for Venezia, 24 p.
2009-17	Peter Nijkamp Roger Stough Mediha Sahin	Impact of social and human capital on business performance of migrant entrepreneurs – a comparative Dutch-US study, 31 p.
2009-18	Dres Creal	A survey of sequential Monte Carlo methods for economics and finance, 54 p.
2009-19	Karima Kourtit André de Waal	Strategic performance management in practice: Advantages, disadvantages and reasons for use, 15 p.
2009-20	Karima Kourtit André de Waal Peter Nijkamp	Strategic performance management and creative industry, 17 p.
2009-21	Eric de Noronha Vaz Peter Nijkamp	Historico-cultural sustainability and urban dynamics – a geo-information science approach to the Algarve area, 25 p.
2009-22	Roberta Capello Peter Nijkamp	Regional growth and development theories revisited, 19 p.
2009-23	M. Francesca Cracolici Miranda Cuffaro Peter Nijkamp	Tourism sustainability and economic efficiency – a statistical analysis of Italian provinces, 14 p.
2009-24	Caroline A. Rodenburg Peter Nijkamp Henri L.F. de Groot Erik T. Verhoef	Valuation of multifunctional land use by commercial investors: A case study on the Amsterdam Zuidas mega-project, 21 p.
2009-25	Katrin Oltmer Peter Nijkamp Raymond Florax Floor Brouwer	Sustainability and agri-environmental policy in the European Union: A meta-analytic investigation, 26 p.
2009-26	Francesca Torrieri Peter Nijkamp	Scenario analysis in spatial impact assessment: A methodological approach, 20 p.
2009-27	Aliye Ahu Gülümser Tüzin Baycan-Levent Peter Nijkamp	Beauty is in the eyes of the beholder: A logistic regression analysis of sustainability and locality as competitive vehicles for human settlements, 14 p.

2009-28	Marco Percoco Peter Nijkamp	Individual time preferences and social discounting in environmental projects, 24 p.
2009-29	Peter Nijkamp Maria Abreu	Regional development theory, 12 p.
2009-30	Tüzin Baycan-Levent Peter Nijkamp	7 FAQs in urban planning, 22 p.
2009-31	Aliye Ahu Gülümser Tüzin Baycan-Levent Peter Nijkamp	Turkey's rurality: A comparative analysis at the EU level, 22 p.
2009-32	Frank Bruinsma Karima Kourtit Peter Nijkamp	An agent-based decision support model for the development of e-services in the tourist sector, 21 p.
2009-33	Mediha Sahin Peter Nijkamp Marius Rietdijk	Cultural diversity and urban innovativeness: Personal and business characteristics of urban migrant entrepreneurs, 27 p.
2009-34	Peter Nijkamp Mediha Sahin	Performance indicators of urban migrant entrepreneurship in the Netherlands, 28 p.
2009-35	Manfred M. Fischer Peter Nijkamp	Entrepreneurship and regional development, 23 p.
2009-36	Faroek Lazrak Peter Nijkamp Piet Rietveld Jan Rouwendal	Cultural heritage and creative cities: An economic evaluation perspective, 20 p.
2009-37	Enno Masurel Peter Nijkamp	Bridging the gap between institutions of higher education and small and medium-size enterprises, 32 p.
2009-38	Francesca Medda Peter Nijkamp Piet Rietveld	Dynamic effects of external and private transport costs on urban shape: A morphogenetic perspective, 17 p.
2009-39	Roberta Capello Peter Nijkamp	Urban economics at a cross-yard: Recent theoretical and methodological directions and future challenges, 16 p.
2009-40	Enno Masurel Peter Nijkamp	The low participation of urban migrant entrepreneurs: Reasons and perceptions of weak institutional embeddedness, 23 p.
2009-41	Patricia van Hemert Peter Nijkamp	Knowledge investments, business R&D and innovativeness of countries. A qualitative meta-analytic comparison, 25 p.
2009-42	Teresa de Noronha Vaz Peter Nijkamp	Knowledge and innovation: The strings between global and local dimensions of sustainable growth, 16 p.
2009-43	Chiara M. Travisi Peter Nijkamp	Managing environmental risk in agriculture: A systematic perspective on the potential of quantitative policy-oriented risk valuation, 19 p.
2009-44	Sander de Leeuw	Logistics aspects of emergency preparedness in flood disaster prevention, 24 p.

	Iris F.A. Vis Sebastiaan B. Jonkman	
2009-45	Eveline S. van Leeuwen Peter Nijkamp	Social accounting matrices. The development and application of SAMs at the local level, 26 p.
2009-46	Tibert Verhagen Willemijn van Dolen	The influence of online store characteristics on consumer impulsive decision-making: A model and empirical application, 33 p.
2009-47	Eveline van Leeuwen Peter Nijkamp	A micro-simulation model for e-services in cultural heritage tourism, 23 p.
2009-48	Andrea Caragliu Chiara Del Bo Peter Nijkamp	Smart cities in Europe, 15 p.
2009-49	Faroek Lazrak Peter Nijkamp Piet Rietveld Jan Rouwendal	Cultural heritage: Hedonic prices for non-market values, 11 p.
2009-50	Eric de Noronha Vaz João Pedro Bernardes Peter Nijkamp	Past landscapes for the reconstruction of Roman land use: Eco-history tourism in the Algarve, 23 p.
2009-51	Eveline van Leeuwen Peter Nijkamp Teresa de Noronha Vaz	The Multi-functional use of urban green space, 12 p.
2009-52	Peter Bakker Carl Koopmans Peter Nijkamp	Appraisal of integrated transport policies, 20 p.
2009-53	Luca De Angelis Leonard J. Paas	The dynamics analysis and prediction of stock markets through the latent Markov model, 29 p.
2009-54	Jan Anne Annema Carl Koopmans	Een lastige praktijk: Ervaringen met waarderen van omgevingskwaliteit in de kosten-batenanalyse, 17 p.
2009-55	Bas Straathof Gert-Jan Linders	Europe’s internal market at fifty: Over the hill? 39 p.
2009-56	Joaquim A.S. Gromicho Jelke J. van Hoorn Francisco Saldanha-da-Gama Gerrit T. Timmer	Exponentially better than brute force: solving the job-shop scheduling problem optimally by dynamic programming, 14 p.
2009-57	Carmen Lee Roman Kraeussl Leo Paas	The effect of anticipated and experienced regret and pride on investors’ future selling decisions, 31 p.
2009-58	René Sitters	Efficient algorithms for average completion time scheduling, 17 p.

2009-59	Masood Gheasi Peter Nijkamp Piet Rietveld	Migration and tourist flows, 20 p.

2010-1	Roberto Patuelli Norbert Schanne Daniel A. Griffith Peter Nijkamp	Persistent disparities in regional unemployment: Application of a spatial filtering approach to local labour markets in Germany, 28 p.
2010-2	Thomas de Graaff Ghebre Debrezion Piet Rietveld	Schaalsprong Almere. Het effect van bereikbaarheidsverbeteringen op de huizenprijzen in Almere, 22 p.
2010-3	John Steenbruggen Maria Teresa Borzacchiello Peter Nijkamp Henk Scholten	Real-time data from mobile phone networks for urban incidence and traffic management – a review of application and opportunities, 23 p.
2010-4	Marc D. Bahlmann Tom Elfring Peter Groenewegen Marleen H. Huysman	Does distance matter? An ego-network approach towards the knowledge-based theory of clusters, 31 p.
2010-5	Jelke J. van Hoorn	A note on the worst case complexity for the capacitated vehicle routing problem, 3 p.
2010-6	Mark G. Lijesen	Empirical applications of spatial competition; an interpretative literature review, 16 p.
2010-7	Carmen Lee Roman Kraeussl Leo Paas	Personality and investment: Personality differences affect investors' adaptation to losses, 28 p.
2010-8	Nahom Ghebrihiwet Evgenia Motchenkova	Leniency programs in the presence of judicial errors, 21 p.
2010-9	Meindert J. Flikkema Ard-Pieter de Man Matthijs Wolters	New trademark registration as an indicator of innovation: results of an explorative study of Benelux trademark data, 53 p.
2010-10	Jani Merikivi Tibert Verhagen Frans Feldberg	Having belief(s) in social virtual worlds: A decomposed approach, 37 p.
2010-11	Umut Kilinç	Price-cost markups and productivity dynamics of entrant plants, 34 p.
2010-12	Umut Kilinç	Measuring competition in a frictional economy, 39 p.

2011-1	Yoshifumi Takahashi Peter Nijkamp	Multifunctional agricultural land use in sustainable world, 25 p.
2011-2	Paulo A.L.D. Nunes Peter Nijkamp	Biodiversity: Economic perspectives, 37 p.
2011-3	Eric de Noronha Vaz Doan Nainggolan Peter Nijkamp Marco Painho	A complex spatial systems analysis of tourism and urban sprawl in the Algarve, 23 p.
2011-4	Karima Kourtit Peter Nijkamp	Strangers on the move. Ethnic entrepreneurs as urban change actors, 34 p.
2011-5	Manie Geyer Helen C. Coetzee Danie Du Plessis Ronnie Donaldson Peter Nijkamp	Recent business transformation in intermediate-sized cities in South Africa, 30 p.
2011-6	Aki Kangasharju Christophe Tavéra Peter Nijkamp	Regional growth and unemployment. The validity of Okun's law for the Finnish regions, 17 p.
2011-7	Amitrajeet A. Batabyal Peter Nijkamp	A Schumpeterian model of entrepreneurship, innovation, and regional economic growth, 30 p.
2011-8	Aliye Ahu Akgün Tüzin Baycan Levent Peter Nijkamp	The engine of sustainable rural development: Embeddedness of entrepreneurs in rural Turkey, 17 p.
2011-9	Aliye Ahu Akgün Eveline van Leeuwen Peter Nijkamp	A systemic perspective on multi-stakeholder sustainable development strategies, 26 p.
2011-10	Tibert Verhagen Jaap van Nes Frans Feldberg Willemijn van Dolen	Virtual customer service agents: Using social presence and personalization to shape online service encounters, 48 p.
2011-11	Henk J. Scholten Maarten van der Vlist	De inrichting van crisisbeheersing, de relatie tussen besluitvorming en informatievoorziening. Casus: Warroom project Netcentrisch werken bij Rijkswaterstaat, 23 p.
2011-12	Tüzin Baycan Peter Nijkamp	A socio-economic impact analysis of cultural diversity, 22 p.
2011-13	Aliye Ahu Akgün Tüzin Baycan Peter Nijkamp	Repositioning rural areas as promising future hot spots, 22 p.
2011-14	Selmar Meents Tibert Verhagen Paul Vlaar	How sellers can stimulate purchasing in electronic marketplaces: Using information as a risk reduction signal, 29 p.

2011-15	Aliye Ahu Gülümser Tüzin Baycan-Levent Peter Nijkamp	Measuring regional creative capacity: A literature review for rural-specific approaches, 22 p.
2011-16	Frank Bruinsma Karima Kourtit Peter Nijkamp	Tourism, culture and e-services: Evaluation of e-services packages, 30 p.
2011-17	Peter Nijkamp Frank Bruinsma Karima Kourtit Eveline van Leeuwen	Supply of and demand for e-services in the cultural sector: Combining top-down and bottom-up perspectives, 16 p.
2011-18	Eveline van Leeuwen Peter Nijkamp Piet Rietveld	Climate change: From global concern to regional challenge, 17 p.
2011-19	Eveline van Leeuwen Peter Nijkamp	Operational advances in tourism research, 25 p.
2011-20	Aliye Ahu Akgün Tüzin Baycan Peter Nijkamp	Creative capacity for sustainable development: A comparative analysis of European and Turkish rural regions, 18 p.
2011-21	Aliye Ahu Gülümser Tüzin Baycan-Levent Peter Nijkamp	Business dynamics as the source of counterurbanisation: An empirical analysis of Turkey, 18 p.
2011-22	Jessie Bakens Peter Nijkamp	Lessons from migration impact analysis, 19 p.
2011-23	Peter Nijkamp Galit Cohen-blankshtain	Opportunities and pitfalls of local e-democracy, 17 p.
2011-24	Maura Soekijad Irene Skovgaard Smith	The 'lean people' in hospital change: Identity work as social differentiation, 30 p.
2011-25	Evgenia Motchenkova Olgerd Rus	Research joint ventures and price collusion: Joint analysis of the impact of R&D subsidies and antitrust fines, 30 p.
2011-26	Karima Kourtit Peter Nijkamp	Strategic choice analysis by expert panels for migration impact assessment, 41 p.
2011-27	Faroek Lazrak Peter Nijkamp Piet Rietveld Jan Rouwendal	The market value of listed heritage: An urban economic application of spatial hedonic pricing, 24 p.
2011-28	Peter Nijkamp	Socio-economic impacts of heterogeneity among foreign migrants: Research and policy challenges, 17 p.
2011-29	Masood Gheasi Peter Nijkamp	Migration, tourism and international trade: Evidence from the UK, 8 p.
2011-30	Karima Kourtit	Evaluation of cyber-tools in cultural tourism, 24 p.

	Peter Nijkamp Eveline van Leeuwen Frank Bruinsma	
2011-31	Cathy Macharis Peter Nijkamp	Possible bias in multi-actor multi-criteria transportation evaluation: Issues and solutions, 16 p.
2011-32	John Steenbruggen Maria Teresa Borzacchiello Peter Nijkamp Henk Scholten	The use of GSM data for transport safety management: An exploratory review, 29 p.
2011-33	John Steenbruggen Peter Nijkamp Jan M. Smits Michel Grothe	Traffic incident management: A common operational picture to support situational awareness of sustainable mobility, 36 p.
2011-34	Tüzin Baycan Peter Nijkamp	Students’ interest in an entrepreneurial career in a multicultural society, 25 p.
2011-35	Adele Finco Deborah Bentivoglio Peter Nijkamp	Integrated evaluation of biofuel production options in agriculture: An exploration of sustainable policy scenarios, 16 p.
2011-36	Eric de Noronha Vaz Pedro Cabral Mário Caetano Peter Nijkamp Marco Paínho	Urban heritage endangerment at the interface of future cities and past heritage: A spatial vulnerability assessment, 25 p.
2011-37	Maria Giaoutzi Anastasia Stratigea Eveline van Leeuwen Peter Nijkamp	Scenario analysis in foresight: AG2020, 23 p.
2011-38	Peter Nijkamp Patricia van Hemert	Knowledge infrastructure and regional growth, 12 p.
2011-39	Patricia van Hemert Enno Masurel Peter Nijkamp	The role of knowledge sources of SME’s for innovation perception and regional innovation policy, 27 p.
2011-40	Eric de Noronha Vaz Marco Painho Peter Nijkamp	Impacts of environmental law and regulations on agricultural land-use change and urban pressure: The Algarve case, 18 p.
2011-41	Karima Kourtit Peter Nijkamp Steef Lowik Frans van Vught Paul Vulto	From islands of innovation to creative hotspots, 26 p.
2011-42	Alina Todiras Peter Nijkamp Saidas Rafijevas	Innovative marketing strategies for national industrial flagships: Brand repositioning for accessing upscale markets, 27 p.

2011-43	Eric de Noronha Vaz Mário Caetano Peter Nijkamp	A multi-level spatial urban pressure analysis of the Giza Pyramid Plateau in Egypt, 18 p.
2011-44	Andrea Caragliu Chiara Del Bo Peter Nijkamp	A map of human capital in European cities, 36 p.
2011-45	Patrizia Lombardi Silvia Giordano Andrea Caragliu Chiara Del Bo Mark Deakin Peter Nijkamp Karima Kourtit	An advanced triple-helix network model for smart cities performance, 22 p.
2011-46	Jessie Bakens Peter Nijkamp	Migrant heterogeneity and urban development: A conceptual analysis, 17 p.
2011-47	Irene Casas Maria Teresa Borzacchiello Biagio Ciuffo Peter Nijkamp	Short and long term effects of sustainable mobility policy: An exploratory case study, 20 p.
2011-48	Christian Bogmans	Can globalization outweigh free-riding? 27 p.
2011-49	Karim Abbas Bernd Heidergott Djamil Aïssani	A Taylor series expansion approach to the functional approximation of finite queues, 26 p.
2011-50	Eric Koomen	Indicators of rural vitality. A GIS-based analysis of socio-economic development of the rural Netherlands, 17 p.

2012-1	Aliye Ahu Gülümser Tüzin Baycan Levent Peter Nijkamp Jacques Poot	The role of local and newcomer entrepreneurs in rural development: A comparative meta-analytic study, 39 p.
2012-2	Joao Romao Bart Neuts Peter Nijkamp Eveline van Leeuwen	Urban tourist complexes as Multi-product companies: Market segmentation and product differentiation in Amsterdam, 18 p.
2012-3	Vincent A.C. van den Berg	Step tolling with price sensitive demand: Why more steps in the toll makes the consumer better off, 20 p.
2012-4	Vasco Diogo Eric Koomen Floor van der Hilst	Second generation biofuel production in the Netherlands. A spatially-explicit exploration of the economic viability of a perennial biofuel crop, 12 p.
2012-5	Thijs Dekker Paul Koster Roy Brouwer	Changing with the tide: Semi-parametric estimation of preference dynamics, 50 p.
2012-6	Daniel Arribas Karima Kourtit Peter Nijkamp	Benchmarking of world cities through self-organizing maps, 22 p.
2012-7	Karima Kourtit Peter Nijkamp Frans van Vught Paul Vulto	Supernova stars in knowledge-based regions, 24 p.
2012-8	Mediha Sahin Tüzin Baycan Peter Nijkamp	The economic importance of migrant entrepreneurship: An application of data envelopment analysis in the Netherlands, 16 p.
2012-9	Peter Nijkamp Jacques Poot	Migration impact assessment: A state of the art, 48 p.
2012-10	Tibert Verhagen Anniek Nauta Frans Feldberg	Negative online word-of-mouth: Behavioral indicator or emotional release? 29 p.

2013-1	Tüzin Baycan Peter Nijkamp	The migration development nexus: New perspectives and challenges, 22 p.
2013-2	Haralambie Leahu	European Options Sensitivities via Monte Carlo Techniques, 28 p.
2013-3	Tibert Verhagen Charlotte Vonkeman Frans Feldberg Plon Verhagen	Making online products more tangible and likeable: The role of local presence as product presentation mechanism, 44 p.
2013-4	Aliye Ahu Akgün Eveline van Leeuwen Peter Nijkamp	A Multi-actor multi-criteria scenario analysis of regional sustainable resource policy, 24 p.
2013-5	John Steenbruggen Peter Nijkamp Maarten van der Vlist	Urban traffic incident management in a digital society. An actor-network approach in information technology use in urban Europe, 25 p.
2013-6	Jorge Ridderstaat Robertico Croes Peter Nijkamp	The force field of tourism, 19 p.
2013-7	Masood Gheasi Peter Nijkamp Piet Rietveld	Unknown diversity: A study on undocumented migrant workers in the Dutch household sector, 17 p.
2013-8	Mediha Sahin Peter Nijkamp Soushi Suzuki	Survival of the fittest among migrant entrepreneurs. A study on differences in the efficiency performance of migrant entrepreneurs in Amsterdam by means of data envelopment analysis, 25 p.
2013-9	Kostas Bithas Peter Nijkamp	Biological integrity as a prerequisite for sustainable development: A bioeconomic perspective, 24 p.
2013-10	Madalina-Stefania Dirzu Peter Nijkamp	The dynamics of agglomeration processes and their contribution to regional development across the EU, 19 p.
2013-11	Eric de Noronha Vaz Agnieszka Walczynska Peter Nijkamp	Regional challenges in tourist wetland systems: An integrated approach to the Ria Formosa area, 17 p.
2013-12	João Romão Eveline van Leeuwen Bart Neuts Peter Nijkamp	Tourist loyalty and urban e-services: A comparison of behavioural impacts in Leipzig and Amsterdam, 19 p.
2013-13	Jorge Ridderstaat Marck Oduber Robertico Croes Peter Nijkamp Pim Martens	Impacts of seasonal patterns of climate on recurrent fluctuations in tourism demand. Evidence from Aruba, 34 p.
2013-14	Emmanouil Tranos Peter Nijkamp	Urban and regional analysis and the digital revolution: Challenges and opportunities, 16 p.
2013-15	Masood Gheasi	International financial transfer by foreign labour: An analysis of remittances

	Peter Nijkamp Piet Rietveld	from informal migrants, 11 p.
2013-16	Serenella Sala Biagio Ciuffo Peter Nijkamp	A meta-framework for sustainability assessment, 24 p.